METHOD AND APPARATUS FOR MOBILITY IMPACT MITIGATION IN A PACKET DATA COMMUNICATION SYSTEM

FIELD OF THE INVENTION

The present invention relates generally to the field of wireless communication systems and, more particularly, to a method and apparatus for mobility impact mitigation in a packet data communication system.

BACKGROUND OF THE INVENTION

The Global System for Mobile Communication (GSM) General Packet Radio Service (GPRS) and Enhanced Data for Global Evolution (EDGE) specify transmission and receipt of data in an end-to-end packet transfer mode. GPRS and EDGE permit efficient use of radio and network resources when data transmission characteristics are; i) packet based, ii) intermittent and non-periodic, iii) possibly frequent with small transfers of data, e.g. less than 500 octets, or iv) possibly infrequent with large transfers of data, e.g. more than several hundred kilobytes. User applications may include Internet browsers, electronic mail and so on.

At the time of GPRS conception, the industry did not anticipate streaming and push-to-talk (PTT) applications that would make use of GPRS and EDGE as an underlying wireless transport mechanism. Therefore, there is no existing specified real-time handover procedure for best effort packet data transfers over GRPS/EDGE. Cell

change is currently achieved by simply allowing a mobile to reselect cells as it would in idle mode. This approach to cell reselection causes a mobile station, in packet transfer mode, to abort its packet transfer on one cell and completely re-establish the ongoing transfer on the new cell.

A mobile station normally, whether it moves through the network or remains stationary, performs the cell reselection process. Each Base Transceiver Station (BTS) in the cellular communication system broadcasts a Broadcast Channel Allocation (BA) list on a Broadcast Control Channel (BCCH) or on a Packet Broadcast Control Channel (PBCCH) where a PBCCH is utilized. A mobile station in packet transfer mode, monitors the BCCH or PBCCH signal strength of the cells indicated by the BA list, also known as the neighbor list, and sequentially takes at least one radio signal strength indication (RSSI) measurement sample of a neighbor BCCH or PBCCH in every Time Division Multiple Access (TDMA) frame. The mobile station calculates, for each BCCH or PBCCH, a running average of the RSSI samples over a 5 second period and makes a cell reselection decision based upon these calculated averages.

In an urban area, cell reselection may occur 2 to 4 times per minute, even when the mobile station remains stationary. This is primarily because a mobile station uses the same autonomous cell reselection rules for GPRS/EDGE packet transfer mode as it does in idle mode as briefly described above. Therefore, a mobile station in packet transfer mode might perform cell reselection simply because an adjacent cell has a stronger radio signal than the serving cell for some pre-defined period of time, rather than because of lost coverage from the serving cell.

This cell reselection approach for packet transfer mode creates a problem for data transfer continuity, and is a particular problem for applications such as PTT. For example, assuming that a reselected cell is in the same routing area (RA) as a serving cell, the flow of data in both directions (mobile station to BTS and BTS to mobile station) may be interrupted by cell resection for time periods of approximately 500 ms to 4 seconds. Further, if the reselected cell is in an RA different than the serving cell RA, the time impact may be as much as 8 seconds.

Therefore, what is needed is a method and apparatus for mitigating the impact of data loss which occurs because of cell reselection during packet data communication.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagram representing a wireless communication system having a plurality of cells and in which cells may be grouped into routing areas.

FIG. 2 is a bit map format diagram of a Neighbor Cell Description information element.

FIG. 3 is a bit map format diagram of data octets transmitted to a mobile station from a network base station, in accordance with an embodiment of the present invention.

FIG. 4 is a flow diagram representing autonomous cell reselection avoidance in accordance with an embodiment of the present invention.

FIG. 5 is a flow diagram representing a packet data mode specific cell reselection based on a network parameter in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

A first aspect of the present invention is a method of cell reselection by a mobile station communicating with a serving cell. The mobile station receives from the serving cell an information element having an indicator corresponding to the routing area of each one of a set of neighbor cells. Next, the mobile station determines whether a neighbor cell routing area is identical to the serving cell routing area. The mobile station then maintains a connection to the serving cell if the neighbor cell routing area is not identical to the serving cell routing area.

In a second aspect of the present invention, the mobile station likewise receives from the serving cell an information element having an indicator corresponding to the routing area of each one of a set of neighbor cells. Next, the mobile station estimates whether a neighbor cell routing area would provide an acceptable time delay for reselection so as to minimize data loss. The mobile station then maintains a connection to the serving cell if the neighbor cell routing area has an estimated time delay greater than a preset threshold with respect to the serving cell routing area.

In a third aspect of the present invention, the mobile station receives from the serving cell radio link budget criteria for packet transfer mode operation. Next, the mobile station determines whether the radio link budget criteria are acceptable for the serving cell. The mobile station then maintains a connection to the serving cell if the criteria are acceptable.

A fourth aspect of the present invention is a communication system comprising one or more base transceiver stations and one or more mobile stations. The base transceiver station or base transceiver stations are configurable to transmit an information element for indication of whether neighbor list base transceiver stations are associated with a routing area. The mobile station or mobile stations are configurable to receive the information element and to avoid cell reselection based upon the information element.

For a fifth aspect of the present invention, the base transceiver station or base transceiver stations are configurable to transmit a mode specific radio link budget parameter. The mobile station or mobile stations are configurable to receive the mode specific radio link budget parameter and to determine whether to perform cell reselection based upon the mode specific radio link budget parameter.

FIG. 1 is a diagram of a typical cellular communication system for use in explaining the embodiments of the present invention. It is to be understood that the present invention is not limited to the embodiments and may be utilized for other communication systems, such as Wideband Code Division Multiple Access (WCDMA) systems and other advanced generation communication systems. As illustrated in FIG.1, a cellular communication system **100** is comprised of a number of cells **101-117**, each cell having a base transceiver station (BTS) **125** which establishes a radio coverage area.

Additionally, cellular communication systems have a generally hierarchical structure in which a number of cells may be grouped into a control area, and/or further

grouped into a routing area (RA). FIG. 1 illustrates hypothetical RAs **119**, **121**, and **123** each of which contains a number of cells.

It is to be understood that the geometries of radio coverage areas and RAs are typically not perfect geometries and that FIG. 1 makes use of such perfect geometries for simplicity of illustration only. In general, an RA will have boundaries that correspond to the radio coverage areas of the cells it contains, however an RA may also be distributed over non-continuous radio coverage areas. In any case, FIG. 1 illustrates that a mobile station moving from a position x to a position y may cross over the boundaries of several cells and may also cross the boundaries of several RAs. For example, in FIG. 1 a mobile station moving from position x to position y will cross from RA **121** to RA **119**.

As the mobile station moves from position x to position y, it will perform cell reselection. As illustrated in FIG. 1, the cells reselected by the mobile station may, or may not, be within the same RA as the mobile station's serving cell.

In a first embodiment of the present invention the effect of cell reselection on packet data communications, and particularly PTT service, is mitigated by reselection avoidance logic. The mobile station may make an autonomous decision to reselect, or not, based upon knowledge of the target cell RA, and whether the target cell RA is the same as the mobile station's serving cell RA.

Returning to FIG. 1, a mobile station in packet data transfer mode, under the existing cell reselection approach, monitors the BCCH or PBCCH as previously described. The mobile station obtains a list of which BCCH carriers it should monitor by

receiving a Neighbor Cell Description information element. The Neighbor Cell Description information element provides the mobile station with the absolute radio frequency channel numbers of the particular BCCH carriers the mobile station should monitor.

The Neighbor Cell Description information element is defined as a type 3 information element with a length of 17 octets. FIG. 2 is an illustration of the Neighbor Cell Description Element. The Neighbor Cell Description element contains a Cell Channel Description element, with the exception of bits 5 and 6 of the second octet **203**. Bits 5 and 6 of octet 2 **203** correspond to a "BCCH allocation sequence number indication" (BA-IND), and an "Extension Indication" (EXT-IND), respectively.

The Neighbor Cell Description list does not have a means to provide an indication of neighbor cell RA to a mobile station. In embodiments of the present invention, a single bit is used to indicate whether a neighbor cell is in the same RA as the cell transmitting the Neighbor Cell Description information element. In accordance with the present invention, this information is defined and transmitted as an "RAC membership element" information element which comprises an "RAC membership parameters" data structure.

A bit value of 1 corresponding to a logical "TRUE" indicates that a neighbor cell is within the same RA as the serving cell of the mobile station. Likewise, a logical false, which is indicated by a bit value of 0, indicates that a neighbor cell is not within the serving cell RA. Therefore, in FIG. 1, a mobile station in position x for example, may be receiving System Information (SI) messages from a BCCH carrier of cell **109**. Assuming

that the BCCH carrier numbers of cells **105**, **107**, **111**, and **113** are transmitted to the mobile station via the Neighbor Cell Description information element from cell **109**, then the mobile station will also receive the RAC membership element from cell **109** in accordance with the present invention. Because neighbor cells **105**, **107**, **111**, and **113** are located within RA **121** in FIG. 1, each cell will have a bit value = TRUE because RA **121** is the same RA that contains cell **109**. In some embodiments of the present invention the RAC membership element may be transmitted to a mobile station as System Information Type 2 data of two octets in length. Because only 1 bit is required to indicate RA membership of a BCCH carrier of the Neighbor list, the two octets of data can provide RA information for up to 16 BCCH carriers.

FIG. 3 illustrates the basic structure of an RAC membership information element in accordance with the present invention. In FIG. 3, octet 1 **301** provides an information element identifier code. Octet 2 **303** and octet 3 **305** together provide 16 data bits for RA TRUE or RA FALSE indications corresponding to the type 3 Neighbor List information containing the neighbor cell BCCH carriers. In accordance with the present invention, the RAC membership information element may be transmitted from the network to the mobile station as a System Information Type 2 (SI2), dual significance message, SI2bis, SI5, or SI5bis message. Additionally, in some embodiments the second octet **303** may have a number of bits utilized to specify message length for larger systems requiring transmission of more than two octets of indication data.

In accordance with the present invention a mobile station, using PTT and operating in a packet transfer mode, may set an internal timer upon assignment of a

Temporary Block Flow (TBF). More particularly, a mobile station of the present invention may operate in an Extended TBF mode, in which the network will occasionally transmit a "PACKET UPLINK ACK/NACK" message to the mobile station for the purpose of maintaining the TBF mode during temporary inactive periods. The mobile station timer, which is used to determine failure of the network radio link, is initiated or reset upon receipt of the PACKET UPLINK ACK/NACK message from the network. In the case of timer reset, the mobile station remains in the TBF mode. If the timer expires, then the mobile station will perform an abnormal release and begin access retry procedures. In the embodiments of the present invention the state of this mobile station internal timer is used to determine whether the mobile station is in a packet data transfer mode.

If the mobile station is in packet data transfer mode, as determined by the active state of the timer, for example timer T3184 as described in the GSM/EDGE/GPRS specifications, and the mobile station has received the RAC membership information element in accordance with the present invention, then the mobile station may apply an autonomous cell reselection avoidance scheme as illustrated by FIG. 4.

In FIG. 4, a mobile station in block **401** begins the determination of whether to perform cell reselection based on any criteria, for example the mobile station may begin to perform cell reselection when a neighbor cell BCCH RSSI is greater than that of the mobile station's serving cell. In accordance with the present invention, the mobile station in block **403** determines whether it is in a packet data transfer mode. The determination of block **403** may be made for example, by monitoring the state of internal timer T3184

which is a timer specified in the GSM/EDGE/GPRS technical specifications. If the timer is in the active state then the mobile station can be considered to be in Extended TBF mode and therefore in a packet data transfer mode.

If the timer is expired, or otherwise not active, then the mobile station may notify the user that the cell connection has been lost, by for example a notification tone or other suitable indication, as in block **413**. The mobile station may then proceed with cell reselection in block **415**.

Returning to block **403**, if the timer is active then the mobile station determines whether it is operating in a PTT mode in block **405**. If not, then the mobile station provides a lost connection indication as in block **413** and proceeds with cell reselection in block **415**. If the mobile station is operating in PTT mode, then the mobile station determines whether sufficient link budget exists, i.e., a radio link budget criterion for the serving cell radio link is met.

There are several aspects involved in the mobile station link budget criteria determination. As previously discussed herein, the process generally involves measuring the RSSI of each neighbor cell BCCH over a period of time, and calculating a running average defined as "RLA_P" in the GSM/EDGE/GPRS technical specifications.

The RLA_P value is further used in calculations to determine a radio signal path loss criterion defined as "C1." In accordance with the GSM/EDGE/GPRS technical specifications, the C1 criterion parameter is calculated for each neighbor cell and the serving cell. If the C1 parameter of the serving cell falls below zero, the mobile station

reselects an appropriate neighbor cell based upon the neighbor cell C1 value and other criteria.

In addition to C1, for GPRS, the mobile station also uses a parameter defined as "C32" which is a cell ranking parameter. The C32 value is used to select a neighbor cell where two or more neighbor cells have equal priority based on other criteria parameters such as C1. A mobile station will make a cell reselection based on two conditions; 1) where the C1 parameter for the serving cell falls below zero, or 2) where a neighbor cell is evaluated as better than the serving cell and has the highest C32 value.

Because the first condition is based upon the serving cell signal strength and is indicative of a failed radio path a cell reselection should be allowed to occur. However, the second condition, based upon the C32 parameter is not so critical and therefore is modified by and in accordance with the embodiments of the present invention disclosed herein.

Therefore, returning to FIG. 4, in block **407** the mobile station determines whether the link budget criteria are met. For example, if the serving cell C1 value drops below zero, the serving cell link is unacceptable and the mobile station will proceed to block **413** and block **415** and, thus, reselect a new cell. However, if the mobile station measures a better neighbor cell criterion, as it would in the C32 parameter condition, then the neighbor cell link is superior and the mobile station will check whether the C32 target cell is within the same RA as the serving cell as illustrated by block **409**. As previously described, the mobile station obtains the neighbor cell RA status via an RAC

Membership information element which corresponds to the BCCH carriers indicated in the neighbor list of the Neighbor Cell Description information element.

If the target cell is not within the same RA as the serving cell, as indicated by an RAC parameter value of FALSE for the target cell, then the mobile station maintains its connection to the serving cell in block **411**. If the target cell RA is identical to the serving cell RA, then the mobile station proceeds with cell reselection in block **413** and block **415**.

The procedure for determining whether to perform cell reselection ends in block **417**. The mobile station may begin the procedure again, based on any criteria, in block **401** or perform another function or functions.

The benefits of the herein described embodiments reduce or prevent the loss of voice data during PTT communication and thus provide an improved PTT communication system over known implementations.

In a second embodiment of the present invention, a network operator may control the reselection processes, for mobile stations in packet data transfer mode, by a predefined network path loss parameter. In accordance with the second embodiment a new parameter is defined as "C1_P" which is applied by the mobile station when operating in a packet data transfer mode, or when using an application that would be severely degraded by frequent cell reselection, such as PTT.

A mobile station operating in packet data transfer mode, which receives the C1_P parameter from the network will ignore the C1 and C32 parameters and will only take

reselection action based upon C1_P. FIG. 5 illustrates a procedure of the second embodiment of the present invention. In FIG. 5, block **501**, a mobile station begins the determination of whether to perform cell reselection based upon any criteria, for example the mobile station may begin to perform cell reselection when a neighbor cell BCCH RSSI is greater than that of the mobile station's serving cell. This operation is the same operation as that of FIG. 4 block **401**.

In block **503**, similar to block 403, the mobile station determines whether it is in a packet data transfer mode. The determination of block **503** is identical to that of block **403**. For example, the mobile station may monitor the state of internal timer T3184. If the timer is in the active state then the mobile station can be considered to be in Extended TBF mode and therefore in a packet data transfer mode.

If the timer is expired, or otherwise not active, then the mobile station may notify the user that the cell connection has been lost, by for example a notification tone or other suitable indication, as in block **513**. The mobile station may then proceed with the cell reselection in block **515**.

Returning to block **503**, if the timer is active then the mobile station determines whether it is operating in a PTT mode in block **505**. If not, then the mobile station provides a lost connection indication as in block **513** and proceeds with cell reselection in block **515**. If the mobile station is operating in PTT mode, then the mobile station determines whether the radio link budget criteria for the serving cell radio link is met.

In block **507**, the mobile station must have received the C1_P parameter such that it may make the link budget determination based upon C1_P in block **509**. If the parameter is not received by the mobile station in block **507**, or if the serving cell link is found unacceptable in block **509**, then the mobile station will proceed to cell reselection blocks **513** and **515**. However, if C1_P has been received in block **507**, and the serving cell radio link remains acceptable in block **509**, then the mobile station maintains its connection to its current serving cell in block **511**.

The procedure for determining whether to perform cell reselection ends in block **517**. The mobile station may begin the procedure again, based on any criteria, in block **501** or perform another function or functions.

It is to be understood that the determination of acceptable radio link in block **509** is based upon the parameter C1_P in accordance with the present invention and that parameters C1 and C32, which the mobile station uses in idle mode, will be ignored in block **509**. Therefore the present invention enables a mode-specific cell reselection procedure for mobile stations in packet transfer mode. A mobile station operating in accordance with the present invention will therefore have an improved data communication, particularly for PTT, as opposed to a mobile station that merely uses the cell reselection procedures of idle mode.

While the preferred embodiment of the invention have been illustrated and described, it is to be understood that the invention is not so limited. Numerous modifications, changes, variations, substitutions and equivalents will occur to those

skilled in the art without departing from the spirit and scope of the present invention as defined by the appended claims.